RESAC Annual Progress Report

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The California Water Resources Research and Applications Center has successfully moved forward on the second year deliverables and has begun advancing our third year work plan to generate improved products, continue to leverage new resources, and further strengthen our interactions among southwestern U.S. research and user communities. The California Water Resources RESAC has continued to produce Regional Climate System Model (RCSM) short-term weather and stream flow predictions, seasonal climate and stream flow predictions, long-term climate variability and impact assessments, and model evaluation. We have performed water quality and sediment related research and applications, including agriculture impact assessments, real-time San Joaquin water quality monitoring, identification of runoff from abandoned mine sites, erosion modeling, sediment transport modeling, and assessments of related hazards. Our RESAC has maintained a two-way flow of information between the RESAC and users, has become a member of the Earth Science Information Partnership as an ESIP 2, contributed to the 2000 Intergovernmental Panel on Climate Change (IPCC), the U.S. National Assessment, and participated in numerous outreach activities. The following provides highlights of fiscal year 2 accomplishments and milestones.

Hydroclimate Simulations and Analysis (J. Kim, P. Kryiakidis, N. Miller, post docs)

During FY2, daily precipitation, temperature, and streamfow forecasts were posted at our RESAC URL (www-esd.lbl.gov/RCC) for the western U.S. during the November to April wet season. We have advanced mesoscale seasonal predictions by applying satellite-observed data. A new set of climate change studies was performed and reported during this period. These studies included the Hadley Centre global climate projections for the period 2040 to 2049, two regional climate models (LBNL/MAS, NCAR/RegCM), and our partnered NWS River Forecast Center's version of the Sacramento model. Statistical downscaling of California precipitation has been further advanced and reported. Two new post docs joined our group in February of this year. Dr. Kathy Bashford is a hydrologic modeler and analyst and Dr. Sue Kemball-Cook is an atmospheric modeler and diagnostician. Both are working with Miller on RESAC projects.

In collaboration with the University of Arizona-Tucson Southwest RESAC, we have improved seasonal and interannual predictions using satellite-observed vegetation characteristics combined with an empirical formulation to create a 3-D vegetation rooting

density distribution. A seasonal simulation experiment shows that the new rooting density data reduces summertime evaporation up to 10% in the western US. The reduced summertime evaporation shows a positive correlation with reduced summer rainfall.

Downscaled climate projections for the scenario period 2040 - 2049 indicated an increase of low level temperature and precipitation over the western US. Low level temperature increased by 2 - 5 ^{o}C over the land surfaces and significantly increased precipitation during the cold seasons (October - March) in Washington, Oregon, and California, especially in mountainous regions. Despite significant increases in winter precipitation along the Pacific Ocean, snowfall may decrease in much of the mountainous regions due to the warmer low atmospheric temperature.

Two mesoscale atmospheric models, RegCM and the MAS, were used as input to the Sacramento Model for 11 major watersheds in California. Both model results showed an increase in mean monthly streamflow during the winter and spring, and a decrease during the summer. The MAS forced streamflow resulted in much larger changes than the RegCM forced streamflow. Results indicated that the high elevation watersheds had an earlier peak flow by 1 to 2 months, while coastal watersheds mainly shifted in magnitude. Both sets of results indicate that the 2040 - 2049 projected climatology resulted in the California study watersheds having winter temperatures increase by 2.5 - 3^{o}C and the summer temperatures increase by 4.5 - 5 ^{o}C. The projected precipitation increase was generally 40-60 percent during the winter, while streamflow in the high elevation Sierra Nevada showed a winter increase of 150 - 300 percent and summertime decreases of about 20 percent. This suggests that flooding may increase during winter wet seasons and water availability during the summer growing season may become more limited.

We developed a stochastic model for daily rainfall, which accounts for serial correlation in both precipitation occurrence and intensity. The parameters of the stochastic precipitation model can be inferred from historical data or from dynamically downscaled precipitation forecasts. Once its parameters are established, the stochastic precipitation model can be used for generating alternative synthetic realizations of daily rainfall. These synthetic realizations share important characteristics with observed (or forecasted) rainfall records, such as seasonality and persistence. The resulting downscaled rainfall will be used as forcing to our landslide prediction work.

We developed a Bayesian approach for propagating uncertainty in the parameters of the stochastic precipitation model to hydrologic response, and particularly to streamflow predictions. This is especially important for properly characterizing uncertainty in streamflow predictions, since the parameters of the stochastic precipitation model are themselves uncertain (especially when derived from seasonal forecasts). In the developed Bayesian approach, we used historical daily precipitation records to form parameter distributions, which were then sampled in a Monte Carlo setting. A real-world case study has shown that the developed uncertainty propagation tool can provide a practical means for delineating uncertainty bounds in forecasted streamflow due to uncertainty in dynamically downscaled precipitation forcing.

We also developed a geostatistical model for mapping the spatial distribution of seasonal precipitation using rain gauge data, lower atmosphere characteristics and their interaction with local terrain. Even though in the current phase the atmospheric data represent interpolated variables from NCEP/NCAR reanalysis nodes, the model is general enough to allow integration of similar variables obtained from dynamically downscaled fields. Results have shown that the developed method allows a more realistic representation of rainfall fields than those using only rain gauge data, e.g., traditional analyses. The integration of dynamically downscaled fields with observations in a data assimilation mode is currently being explored in a space-time framework.

A DOE Water Cycle Pilot study was funded this April. Modeling and measurement at the Walnut Watershed in Kansas will focus on a closed water budget with the implementation of stable water isotopes in the atmospheric and land-surface/hydrologic models.

Agricultural Impacts, Real-Time Monitoring: (N. Quinn, N. Miller, J. Dracup, students)

This activity continues to proceed well with real-time monitoring stations in the San Joaquin River that are on the CA DWR web site and linked to our California Water Resources Research and Applications Center web site. Migration of models onto the USGS Modular Modeling system (MMS) by Nuria Bertram-Ortiz (graduate student) has continued during FY2. Levi Brekke (graduate student) has begun implementation of ECOSIM, a water demand model for the Central Valley. This resulting hydroclimate and impacts system for the Central Valley is being merged within our larger Regional Climate System Model as part of a user friendly assessment tool package.

The San Joaquin River Real-Time Salinity Management project is in its second year. Weekly forecasts of San Joaquin River assimilative capacity for salt are posted at our URL. The project team continues to work with agencies and local water districts to encourage use of these forecasts in making water diversion and drainage decisions. The recent initiative by the Central Valley Regional Water Quality Control Board to develop salinity Total Maximum Daily Loads (TMDL's) for entities discharging drainage to the San Joaquin River has provided a boost to our program.

A CALFED sponsored real-time water quality management project was funded this year dealing with wetland salinity and the ability for wetland managers to adjust wetland drainage release patterns without impacting habitat value. The project will conduct both regional (North Grasslands Basin) and local scale (Salinas Duck Club) mass balance studies to monitor the quality of water imports from the Delta and water returns to the San Joaquin River. A GIS-based water allocation and salinity balance model is under development using NASA and other map products and GIS coverages developed by Ducks Unlimited to reduce the need for intensive long-term monitoring of these systems. This project has been written-up in a mass circulation (3,000 plus subscribers) regional wetland newsletter and continues to attract attention.

The US Bureau of Reclamation provides water for agriculture, manufacturing, industry, and environmental purposes in California and in the western States. Contract amounts are

renegotiated every 10 or more years - in a process whereby the contractor argues for certain contract deliveries based on current and projected land use. This is a very inflexible system that can lead to great inequities, especially in times of shortage when water contractors can make windfall profits by selling their water contracts on the open market. Although the federal Government operates a system of allocation reductions during periods of water shortage, these are applied according to the type of contract rather than according to need. A more efficient, more equitable system would match needs to water delivery. This would require near real-time access to accurate, reliable land use data.

An initiative is underway within the USBR and the LBNL California Water Resources RESAC to provide techniques to interpret NASA satellite imagery 4 times per year in order to develop a new system for determining USBR water allocation. This will likely involve state-of-the-art pattern recognition software development coupled to an expert system or inference engine to assist in land use interpretation. Successful outcome could mean great water savings in western states and the evolution of a new system for water allocation.

Identification of Contaminants from Abandoned Mines: (G. Brimhall, students)

Brimhall and his students (Sanchez and Takagi) have completed a real-time digital mapping study of the Penn Mine. Helicopter and ground based VIS/IR reflectance spectra were used as part of the procedure to identify sites that will require remediation to prevent sulfide runoff. A white reflectance standard for calibrating the visual infrared (VNIR) spectrometer from the helicopter was constructed and showed promising results in initial testing. Visits to many abandoned mine sites in the Foothills cooper and zinc belt resulted in the decision to focus on the dumps of Copperopolis, Newton Mine, and Spenceville Mine. Owners were contacted regarding access to their properties with varying degrees of access being granted to these mine sites. A small-scale ground survey was conducted at Copperopolis.

A fully operational version of Fast Spectral Identification algorithm (FSTSpecID) was completed in November 2000 by Montero and Brimhall and was used to map surface mineralogy in the Spenceville mine in Yuba County, California and Copperopolis in Calaveras County, California.

Mapping of the Spenceville mine site by infrared reflectance spectroscopy revealed several areas on abandoned mine waste dumps where mineral zonation associated with acid mine drainage occurs. In these dumps, minerals that form in low pH, high oxidation environments are found surrounded by aprons of intermediate to high pH minerals such as goethite and hematite. This zonation reveals areas of rapid oxidation of pyrite and dissolution of both ore and gangue minerals present in the waste dumps that translates into release of heavy metals into the adjacent Little Dry Creek. Mapping of property owned by the Copperopolis Fire department in Copperopolis reveals similar patterns but in a smaller scale, that might be negatively affecting the quality of the Copper Creek watershed.

During FY2, three day-long sampling runs were completed for the creek waters draining all of our study sites in the Foothills of the Sierra Nevada where massive volcanogenic deposits

were mined in the last century. The mines include; Copperopolis, Newton and Spenceville mine wastepiles and their associated downstream major river drainages. Analysis of the metals concentrations in these waters by atomic absorption spectroscopy shows that creek chemistry is significantly affected by the mine wastepiles, from which they receive drainage and runoff.

Heavy metal concentrations are highest in the waters of Copper Creek, which runs along the edge of the wastepiles of the Newton Mine. Upstream of the mine waste, Copper Creek water has copper concentrations of 2.4 - 6.8 ppb (parts/billion). Downstream, mid-way through the length of the wastepiles, copper concentrations are much higher, at 0.6 - 4.3 ppm (parts/million), and are even higher at the point where the creek has run the full length of the wastepiles, 6.9 - 15.35 ppm. Iron behaves in a similar manner, with ppb-level concentrations upstream of the mine wastepiles, and ppm-level concentrations mid-way (55.2 - 56.7 ppm) and at the end of the length of the wastepiles (16.0 - 217.3 ppm).

At Spenceville, the metal concentrations in Little Dry Creek are also elevated by the mine waste, but to a lesser extent. Upstream of the dumps, Little Dry Creek has barely detectable copper (<1 ppb). Copper concentrations increase downstream (35.6 - 80.0 ppb) as the creek comes into contact with mine waste, drainage and runoff. They are even higher at the sampling site after Little Dry Creek has run the length of the mine wastepiles (93.2 - 141.6 ppb), just before draining into the much larger Dry Creek. Dry Creek, in turn, is affected by incoming copper from Little Dry Creek, and by additional drainage and runoff from the dumps themselves.

Landslide and Sediment Transport: (M. Casadei, W. Dietrich, N. Miller, students)

During FY2, we developed and tested a coupled slope stability-hydrological distributed model that computes the fluctuation of pore pressure within the soil mantle during and after heavy rainfall. This model, Cassandra, can be used to estimate the timing and location of the sites where landslides start failing and moving downhill.

We have used historical records of rainfall and mapped landslides as an input to our model to verify the degree of accuracy of the model predictions as a hindcast simulation. The Cassandra model represents an attempt to model the hydrological response of a hillslope catchment with a minimum set of parameters, using the most widely available data, 5 - 10m grid DEMs, and daily precipitation records.

The 2-layer hydrological model uses an organization of storage similar to TOPMODEL, accounting for evapotranspiration and unsaturated zone storage. The hydrological model computes the water table elevation, which is then used to calculate the factor of safety of every site in the areas of interest. The factor of safety (FS) is defined as the ratio between resistant and driving forces along the critical slip surface. When FS is less than zero, then the soil block fails and a landslide occurs. The model generates the FS map at any given time, so that the user can observe the expected unstable sites and the variation of the instability pattern in time.

We selected a small catchment near the city of El Granada, in the Montara Mountains (San Mateo County, California) to calibrate the Cassandra model. Bedrock lithology consists of Montara Diorite, a medium to coarse granitic rock, quartz diorite with some granodiorite, apatite, and pegmatite. The rock is pervasively jointed and fractured, and the topmost 3 to 30 meters are moderately weathered to disintegrated granular soil. Vegetation consists mostly of shrubs and grasslands. The climate of the region is Mediterranean, featuring dry mild summers and moist cold winters. Mean annual rainfall is 750 mm, 80% of which occurs between November through March.

Discrimination of critical events in time is the most important result of community value. The rainfall analysis shows that similar rainfall events do not produce the same results in terms of soil slip mobilization. We compared the results from the original simulation with the new one accounting for previous landsliding. It turns out that during the critical events originally overestimated (especially february 1986), the extent of expected landsliding decreases by a factor of 3 to 4. However, there is still some inherent overestimation, which will probably be hard to avoid.

The spatial variability of some of the above makes it hard to have significant measures, and in this case a calibration procedure is needed; this is especially true for the hydrological parameters and partially for the geomechanical parameters. Applying the calibrated model to other rainstorms resulted in significant overestimation of the number and extent of failures. The tendency of the model to overpredict instability is thought to be due to the mechanism of pore-pressure response to very high-intensity rainstorms (“pressure wave”) and the dynamics of soil removal and recovery in the dangerous hollows after big landsliding episodes (“legacy effect").

We were able to significantly improve the performance of the Cassandra model, including the legacy effect, in simulating (hindcasting) later historical events. We have to stress that the accuracy of the prediction is influenced by the accuracy of the input data, in particular the topography and we are in the process of obtaining fine-scale 4m resolution IKONOS data.

Development of a river network based sediment routing model for mountainous landscapes is underway, in collaboration with Yantao Cui. A preliminary numerical model has been set up for application to the Noyo River in Northern California. As part of this activity a graduate student, Elowyn Yager, has been doing experimental runs on a steep flume to explore the mechanics of sediment transport on shallow, coarse bedded streams.

Southwest RESAC Team (R. Bales, N. Miller)

The integrated Southwestern RESAC Team (Drs. Bales and Miller) have continued to work together on advancing remotely-sensed snow cover area for model improvements. This activity is coupled with the group at the USCOE CRREL (Cold Regions Research Lab) and the UA Hydrology group, as well as the UC-Santa Barbara ESIP (Dr. Frew). Additionally, the Berkeley group has begun to evaluate the UA snow model by Z-Y Liang et al. as an

improvement to the current single layer snow budget model currently in the Berkeley Regional Climate System Model.

The University of Arizona's Hydrology and Water Resources Department has made Miller an Adjunct Professor in September 2000. This will strengthen our joint research through the co-advising of students on shared projects. Fan Li (UA Graduate Student) has been using our soil moisture output data for analysis and is working jointly with Bales and Miller on her Ph.D. Prof.s Bales and Miller submitted a proposal on multi-scale hydroclimate modeling and data assimilation for analysis of surface hydrologic variability.

Consortium meetings/communications

Miller attended the 5th ESIP Federation Assembly in Dover, NH July 11-13 as a representative of the newly elected Berkeley RESAC ESIP Type 2.

Miller attended the California Energy Commission's Climate Change Workshop July 12-13 in Sacramento. Plans for a multiple climate scenarios and impacts study for California were formulated.

Quinn held a Decision Support System workshop Aug. 29 in Berkeley. This all day meeting had attendees from the California Dept. of Water Resources, the Bureau of Reclamation, as well as scientists from Berkeley Lab, UC-Berkeley, Australia, Canada, and Germany.

Miller represented both the California Water resources RESAC and the Southwestern RESAC at the NASA Geospatial Applications Conference Sept. 11-12 in Sacramento. Our applications poster was set up along with other RESAC and ESIP posters.

Miller and Kim participated in the DOE Climate Change Prediction Program Workshop, the NOAA GEWEX America Prediction Program, and the multi-agency Water Cycle Initiative Workshop all in Bethesda, MD during the last week of March.

Miller and Kim participated in the NASA Investigators Working Group Meeting, April 11-12, held in Tucson, AZ. We presented our RESAC Results in a Poster Presentation next to the Tucson RESAC. An additional planning meeting took place on hydrology and climate, as well as RESAC planning of satellite-derived snow cover area and snow water equivalent.

Miller presented the Berkeley RESAC Significant Results at the RESAC Annual Review Meeting, May 11-13, held at Stennis Space Flight Center.

As a member of the California Climate Change Panel, Miller represented the Berkeley RESAC on regional climate and uncertainty analysis during a CA Energy Commission sponsored workshop held on June 10-11, held in Sacramento, CA

The hydrology sub-group of the Berkeley RESAC held a 2 day workshop with George Leavesley from the USGS Water Resources Division to advance our implementation of the

Modular Modeling System (MMS) and the Object Oriented Users Interface (OUI). This set of tools will tighten our research with our sister RESAC at Tucson, as well as the many other users that are now migrating onto the MMS platform.

The Berkeley RESAC held an all hands meeting on June 27 to discuss the Annual Review that took place in Stennis and a number of sub-group working meetings took place during FY2. Each investigator presented new significant results and indicated future directions toward strengthening our water resources research and applications focus.

The Earth Science Information Partnership (ESIP) Federation elected the Berkeley RESAC as the first voted member in late June. Miller represented the Berkeley RESAC as an ESIP Type 2 at the 5th ESIP Federation Assembly in New Hampshire, July 11-13.

We held a California Modeling and Information Workshop on September 18 in Berkeley. This was attended by more than 50 representatives from the research and applications community from the state government. Several talks on decision support system were presented with a large amount of follow-on discussion.

Quinn met with a number of California Water Resource state agencies during this quarter. He presented the water quality research and monitoring activities, as well as our efforts to migrate all land-surface modeling onto the USGS Modular Modeling System (MMS) platform. We are coordinating activities with the USGS to migrate the USBR tools onto MMS for the California domain.

Outreach activities for this period.

Outreach during the April to July 2000 period consisted of meetings with CA state agencies (CA Energy Comm, Dept. Water Resources, Dept.) and Federal Agencies (USGS, DOE, EPA, and NASA). Community outreach includes the all day presentation of the Berkeley RESAC during the Berkeley Lab Open House in May.

The primary outreach consisted of the Southwest Assessment Report and several related reports listed below. We have maintained our strong ties to the local and state agencies and are gaining federal agency recognition for multi-agency collaboration in California.

Quinn has met with agency staff in the California Department of Water Resources, Central Valley Water Quality Control Board, US Fish and Wildlife Service and US Bureau of Reclamation to provide updates on all of these projects and explore opportunities for cooperative research and monitoring.

We have contributed to the USGCRP U.S. National Assessment Reports of the West, Coastal, Water Sector, as well as the IPCC Report (WG1, TAR, Chapt 10. Regional Climate Information – Evaluation and Projections).

Meetings with the Coordinated Resource Management Program (CRMP) in Fresno and Mendota California (Quinn and Miller)

The Berkeley RESAC is now linked to the ESIP Federation and will have increased visibility.

Wet season forecasts are posted on the California Water Resources RESAC URL

Product, process, service prototypes

- Daily forecasts of precipitation, temperature, and streamflow posted on our URL during the wet season (November - April).
- California streamflow sensitivities of 11 basins for application to water demand simulations used by the CA Department of Water Resources.
- California streamflow 10 year data sets for control and change climates.
- Gridded 36km 10 year data sets for atmospheric, land-surface and soil moisture control and change climates.
- Landslide Model maps of topographic gradient, contributing area, soil thickness, the factor of safety, water table elevation, and the unsaturated soil water content are available.
- San Joaquin salinity monitoring is available from our URL.

State and Federal Committees/Advisory groups:

- NASA Climate and Hydrology Committee - Miller and Kim member
- California Climate Change Panel - Miller member
- California, Southwest, and National Assessment Science Team - Miller member
- Bay-Delta Modeling Forum - Quinn Technical Committee Chair
- Stockton Dissolved Oxygen Technical Advisory Committee - Quinn member
- San Joaquin River Management Program - Quinn member

Publications:

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Kemball-Cook, S., and B. Wang, 2001: Equatorial waves and air-sea interaction in the boreal summer intraseasonal oscillation. Journal of Climate, in press.

Kemball-Cook, S., and B.C. Weare, 2001: The onset of convection in the Madden-Julian oscillation. Journal of Climate. V14, pp 780-793.

Holmes K.W., O.A. Chadwick, and P.C. Kyriakidis, 2000: Error in a USGS 30m digital elevation model, and an evaluation of its effects on digital terrain modeling. Journal of Hydrology, 233(1-4), 156-175

Kim, J., N. Miller, J. Farrara, and S. Hong, 2000: A numerical study of precipitation and streamflow in the western United States during the 1997/1998 winter season. J. Hydrometeorol., 1, 311-329.

Kyriakidis, P.C., N.L. Miller, and J. Kim (2001): Uncertainty Propagation of Regional Climate Precipitation Forecasts to Hydrologic Impact Assessment, Journal of Hydrometeorology (in press)

Kyriakidis, P.C., J. Kim, and N. L. Miller (2001): Geostatistical Mapping of Precipitation using Atmospheric and Terrain Characteristics, Journal of Applied Meteorology (accepted for publication)

Miller, N.L. (Contributing Author).2000: Preparing for a changing Climate. The potential consequences of climate variability and change. Southwest. U.S. Global Change Research Program. 60 pp. ISPE.

Miller, N.L. (Contributing Author) 2000: Climate change impacts on the United States. The potential consequences of climate variability and change. Overview. U.S. Global Change Research Program. 154 pp. Cambridge University Press.

Presentations:

Casadei M., Dietrich W.E., Miller, N.L., 2000: CASSANDRA: A Storm-Based Distributed Hydrological Model for Debris-Flow Forecasting. AGU Fall meeting 2000 – Hydrology Session, EGS, March 2001, Nice, France.

Kemball-Cook, S. and B. Wang, 2000: Equatorial waves and air-sea interaction in the boreal summer intraseasonal oscillation. . 25th Climate Diagnostics and Prediction Workshop, Nov., 2000, Palisades, NY.

Kim, J., N. L. Miller, T. Kim, J. D. Farrara, and X. Zeng, 2000: Effects of land-surface characterization on simulating summertime precipitation: Implications on warm-season extended forecasts. Proceedings in 2nd Southwest Weather Symposium, Oct., 2000, Tucson, AZ.

Kim, J., N. L. Miller, T. Kim, and X. Zeng, 2000: Sensitivity of the simulated summer hydrologic cycle of the western U.S. to land-surface characterizations and its implications for warm-season predictions. 25th Climate Diagnostics and Prediction Workshop, Nov., 2000, Palisades, NY.

Kim, J., N. L. Miller, T. Kim, and X. Zeng, 2000: Sensitivity of the summer hydrologic cycle of the western U.S. to rooting density. Fall AGU meeting, Dec. 2000, San Francisco.

Li, Fan, R. C. Bales, H. Hartman, Z.-L. Yang, J. Kim, N.L. Miller and S. Sorooshian, 2000: Evaluating Seasonal Snow Simulations from a Regional Climate Model in the Western U.S. with High-Elevation Data Sets. Fall AGU meeting, Dec. 2000, San Francisco.

Miller, N.L., J. Kim, W.J. Gutowski Jr., Z. Pan, R.W. Arritt, E. S. Takle, E. Strem, R. Hartman: 2000: California streamflow analysis: Present day and a 2040 to 2049 climate change scenario. Fall AGU meeting, Dec. 2000, San Francisco.

Miller, N.L. Climate and streamflow analysis for impact assessment models. Bay-Delta Modeling Forum, Monterey, CA, Feb. 2001.

Takagi, Tina K., Montero Sánchez, Irene C., and Brimhall, George H, "A simple and inexpensive diffuse reflectance standard target for accurate calibration in low-altitude airborne Ultraviolet-Visible-Near Infrared (UV/VIS/NIR) spectroscopy." Geological Society of America Abstracts with Programs. Vol. 32, no. 7: p. A-372.

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